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ELECTRIC POWER ENGINEERING CENTRE

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UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Draft Guideline for the connection of small-scale inverter based distributed generation

EEA Asset Management Forum 22 June 2016

Dr Richard Strahan

Outline

1. Introduction and Issues to Address
2. Methodology to develop the DG Guideline
3. DG Connection Application Assessment Process
4. DG Installation and Inverter Key Technical Requirements
5. Pro forma DG Application Form

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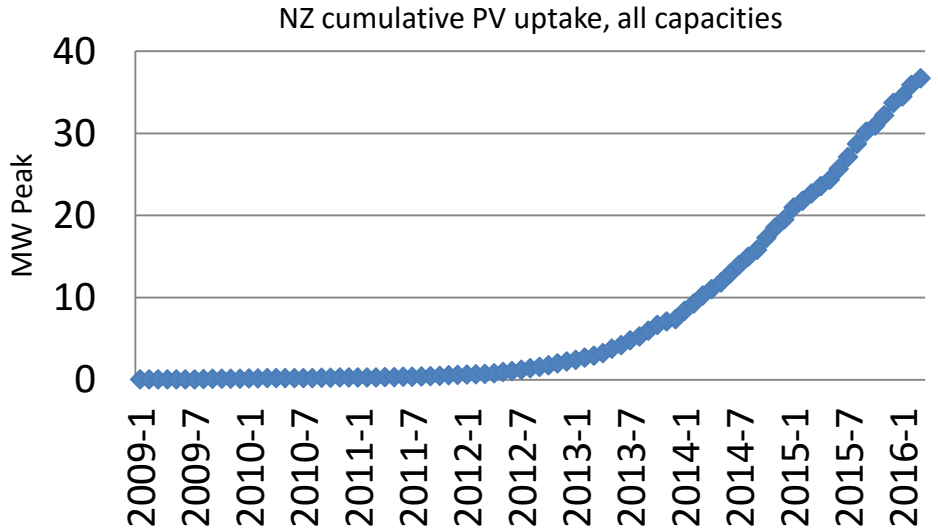
Introduction and Issues to Address:

Growth of PV based Generation in NZ

- PV based DG increased by a factor of 1.6 over the last year
- 90% of installed PV capacity is made up of small-scale residential grid-tied systems rated below 10 kW
- This corresponds to about 300-400 new PV systems being installed each month within LV networks



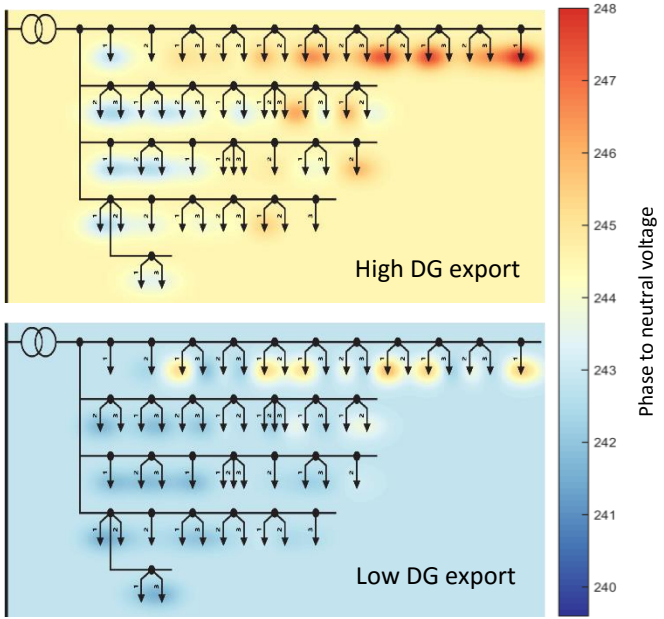
Introduction and Issues to Address:

Reverse power flow

DG can introduce reverse power flow into the LV network, which causes issues of:

- Over-voltage (>1.06 p.u.)
- Phase imbalance
- Over-loading of conductors
- Over-loading of transformer
- Safety and Protection

Simulation of LV Network over-voltage



Maximum permitted voltage rise from the transformer to the point of supply is only 0.02 p.u., i.e. 4.6 V

Introduction and Issues to Address:

DG Connection Application Assessment

The Situation

- SSDG applications are typically processed without technical assessment?
- No consistent approach to assessing applications and connection requirements across EDB's
- Technical complexity of assessment compounded by introduction of advanced inverter technology – as captured in the new *AS/NZS 4777.2 (2015) – Grid connection of energy systems via inverters – Part 2: Inverter Requirements*

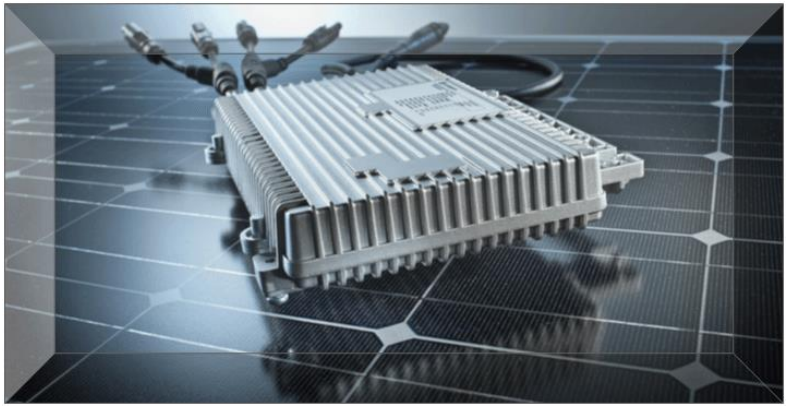
Some Questions

- What criteria does an EDB use to assess a connection application under EIPC 2010 Schedule 6.1, Part 1A up to 10 kW export power?
- What information does the EDB need from the applicant on the DG application form?
- Can an application be auto-assessed, and if so, when should an application be manually assessed?
- Are there circumstances when an applicant can use low cost inverter technology (e.g. which does not have power quality response modes)?

Providing consistent connection requirements and standardization across EDBs would be of major benefit to installers, inverter manufacturers, and consumers

Introduction and Issues to Address:

AS/NZS 4777.2 (2015) – Grid connection of energy systems via inverters – Part 2: Inverter Requirements



Questions

- What inverter protection settings are appropriate for NZ?
- How should inverter power quality response modes be applied here?
- Does AS/NZS 4777.2 provide all the appropriate information and suitable requirements for the NZ context?
- Can inverters actually perform as required?
- What are the technical requirements for the installation?

Introduction and Issues to Address:

Export Congestion

The Situation

- The Code requires each EDB to publically disclose a list of all locations on its distribution network that it knows to be subject to export congestion; or expects to be subject to export congestion within the next 12 months
- Manual assessment of NZ's many thousands of LV networks may be impractical

Some Questions

- Is there a simple method that automates congestion evaluation for each LV network, such that only a much smaller subset of networks would be flagged for needing closer assessment?
- Could this method provide a simple parameter describing the degree of congestion for any LV network for planning purposes?

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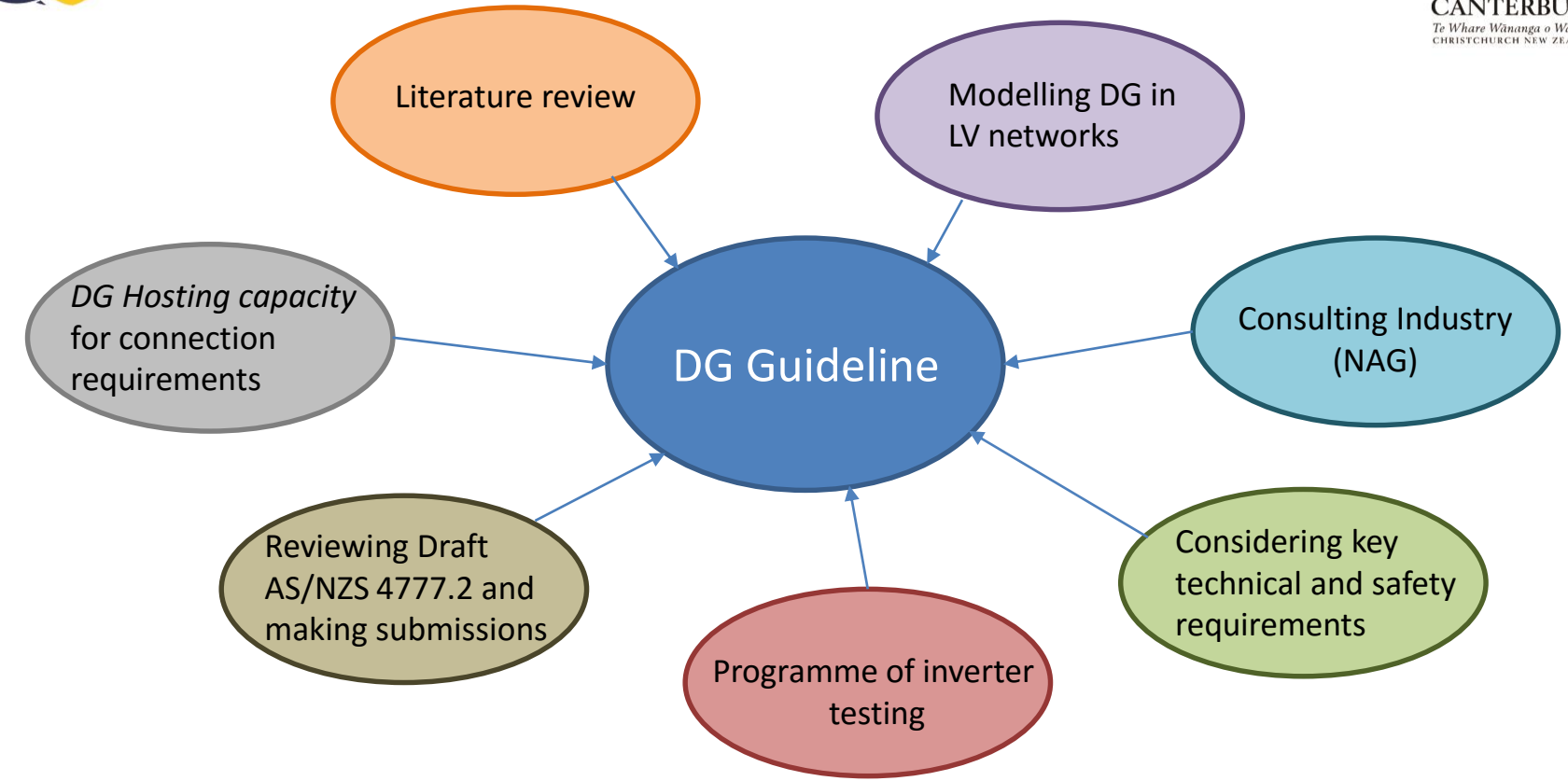
Methodology to develop the DG Guideline



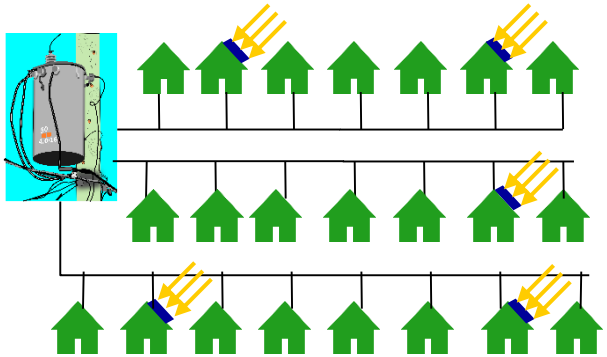
Methodology to develop the DG Guideline:

Review of AS 4777 update to AS/NZS 4777 – Grid connection of energy systems via inverters

Existing Parts	Replacement Parts
AS 4777.1:2005 – Installation requirements ➢ Listed in the Electrical (Safety) Regulations 2010, under Schedule 2	Draft AS/NZS 4777.1:2016 – Installation requirements ➢ GREEN Grid made submission to Standards Australia on behalf of NAG, in May 2016
AS 4777.2:2005 – Inverter requirements AS 4777.3:2005 – Grid protection requirements	AS/NZS 4777.2:2015 – Inverter requirements ➢ Standard now in use, but it states a transitional period until 9th October 2016 during which AS 4777.2 and AS 4777.3, which it supercedes, may also be used. ➢ GREEN Grid made submission to Standards Australia on behalf of the NAG, in May 2014, and May 2015.

Methodology to develop the DG Guideline:

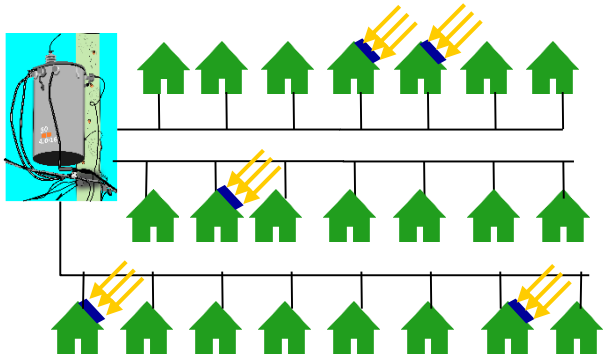
Applying *Hosting Capacity* to determine connection requirements



- ***DG hosting capacity*** is defined as *the maximum real export power (in Watts), per ICP with DG installed, on a LV network which can be tolerated without causing voltage or current limits to be exceeded in the network*.

Methodology to develop the DG Guideline:

Applying *Hosting Capacity* to determine connection requirements



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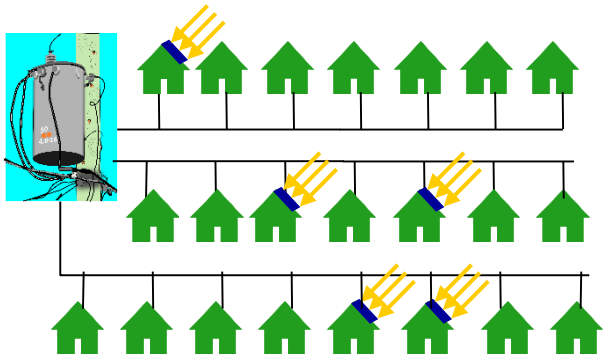

- ***DG hosting capacity*** is defined as *the maximum real export power (in Watts), per ICP with DG installed, on a LV network which can be tolerated without causing voltage or current limits to be exceeded in the network*.

- It is calculated for two thresholds, which are:
  1. a lower connection threshold H_1 above which mitigation measures are necessary,
  2. an upper connection threshold H_2 above which mitigation via inverter reactive power control alone (specifically the Volt-VAr response mode) enabled for all connected DG, is insufficient.

- Hosting capacity is calculated via either full simulation (recommended) or by an approximation method such as the EPECentre's *DGHost*

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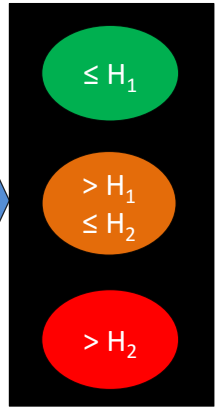
DG Connection Application Assessment Process:

Traffic light system

Customer applies to connect DG (they specify *max real export power*)

EDB assesses application based on network hosting capacity for customer's location



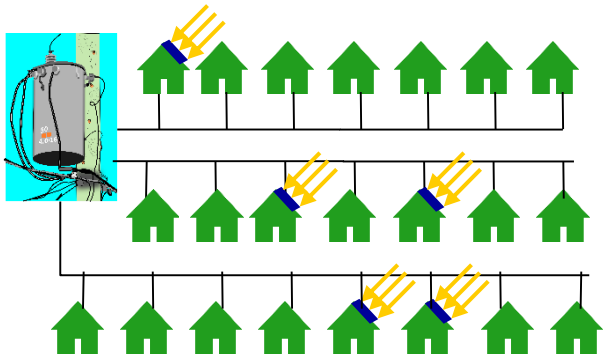
- Green: application auto-assessed and approved
- Amber: application auto-assessed and approved subject to requirement for inverter Volt-VAr response available and enabled
- Red: application manually assessed

Assessment Example

Customer DG Application	LV Network Hosting Capacity Outputs	
Max real export power [kW]	Connection threshold H_1 [kW] (upper limit for no mitigation)	Connection threshold H_2 [kW] (upper limit with mitigation – Volt-VAr response)
4.5	2.7	7.2

DG Connection Application Assessment Process:

22 ICP network with 5 exporting DG



Penetration level = 5/22 = 23%

Penetration level

- *Penetration level (PL)* is defined as *the proportion of ICPs in a given network that have export-capable DG installed.*
- Hosting capacity decreases as penetration level increases
- A long term best estimate of the penetration level should be used.
- The guideline recommends a penetration level between 25% to 100%.
- Setting a lower PL ---> increases hosting capacity thresholds ---> reduces manual assessments, allows more lower spec (cheaper) inverters
- Setting a higher PL ---> decreases hosting capacity thresholds ---> increases manual assessments, allows less lower spec (cheaper) inverters. LV network aggregate export capacity increased by having more Volt-VAr capable inverters.

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DG Installation and Inverter Key Technical Requirements:

The Installation

Draft AS/NZS 4777.1 (2016) states that:

- The rating limit for single phase Inverter Energy Systems (IES) is 5 kVA.
  - ⟹ Therefore the maximum current rating for single-phase connected IES is 21.7 A at 230 V.

- For multi-phase IES the unbalance between phases shall be no greater that 5 kVA.
  - ⟹ Therefore, for two phase IES, the rating limit is 10 kVA.

DG Installation and Inverter Key Technical Requirements:

Recommended inverter settings for New Zealand

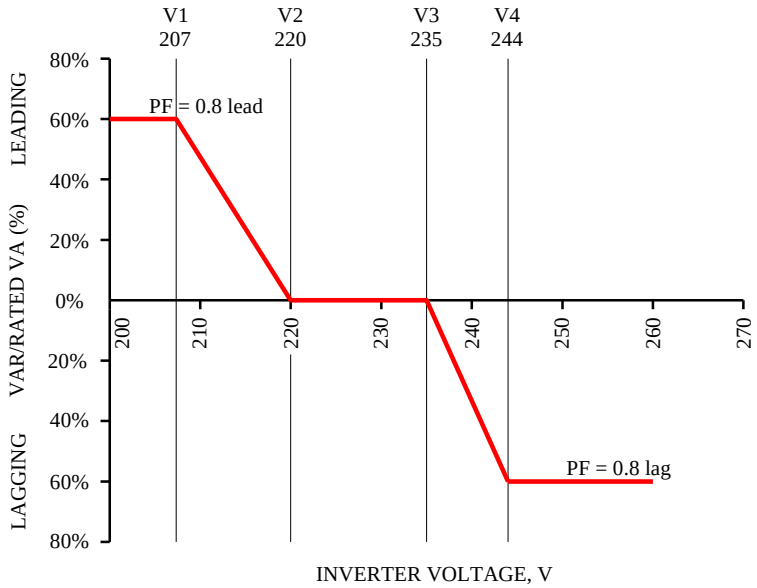
Passive anti-islanding set-point values

Parameter	Limit	Minimum trip delay time	Maximum disconnection (trip) time
$V_{nom\text{-}max}$ (10 minute average)	248 V		
Overvoltage 1	260 V	1 second	2 seconds
Overvoltage 2	265 V	-	0.2 seconds
Undervoltage	180 V	1 second	2 seconds
Under-frequency	45 Hz	1 second	2 seconds
Over-frequency	52 Hz	-	0.2 seconds
Minimum reconnection time	60 Seconds		
Volt response modes: Volt-VAr, Q(V) and Volt-Watt, P(V)	Applicability determined according to GREEN Grid traffic light system GREEN Grid designed Volt-response curves		

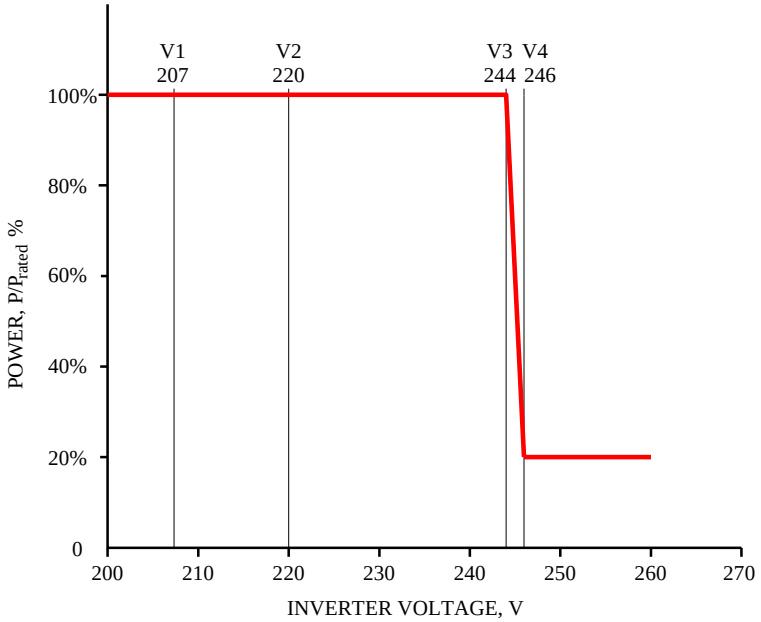
DG Installation and Inverter Key Technical Requirements:

Volt response mode curves for New Zealand

Volt-VAr response mode



Volt-Watt response mode



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Pro forma DG Application Form:

Application to Connect Inverter Based Distributed Generation (DG) of 10kW or less in total

- Located in Appendix A of the Guideline
- 8 pages in length
- Includes questions regarding:
    a) Information the Applicant must provide according to the Code
    b) Information required for the traffic light system
    c) Inverter protection settings
    d) Inverter power quality response modes

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Panel Comments and Participants Questions

Pro forma DG Application Form:

Application to Connect Inverter Based Distributed Generation (DG) of 10kW or less in total

Table headings:

1. Contact details
2. Site details
3. Distributed generation details
4. Intended connection configuration
5. Inverter approval
6. Power export calculation
7. Inverter protection settings
8. Inverter power quality response modes
9. Inverter volt reference values
10. Inverter demand response modes (DRMs)
11. Battery energy storage system (BESS)
12. Power limiting device
13. Installer requirements
14. ICP holder signature

Pre-conference submission

1. *"The DG hosting capacity would see the introduction of equal rationing of local DG capacity."* No, the traffic light system only specifies connection requirements. Connected DG installations will vary in size.
2. For a complete and accurate application, connection must be approved within 10 business days after the distributor receives the application. Problem: "*there is no extra time allowance for manual assessments*" if these are required. Is the answer for the Code to allow more time under Part 1A if the EDB indicates a manual assessment is necessary?
3. A DG may have been procured and installed before application approval, and then the applicant finds out that the EDB requires inverter volt response modes the DG does not have, or operating restrictions or other requirements. How is this dealt with?
   - Note Draft AS/NZS 4777.1 (2016) Clause 3.4.7 states that "*Additional requirements from the electricity distributor may include the activation or connection of … (b) volt response modes*"
4. The Guideline suggests distributors remove inverters from their approved lists that do not have power quality response modes (Section 2.3.4.2.).
5. "*…undertaking detailed and complex modelling as well as lengthening application form requirements may drive additional costs into businesses.*"

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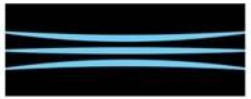

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